PRACTICAL METHODS FOR CHARACTERIZING TRAINING AND IDENTIFYING OVERREACHING IN ATHLETES

by

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ABSTRACT

The training undertaken by athletes to improve performance is a complex process, which attempts to balance the need for progressively overloading the proper physiological systems with adequate recovery time. Without adequate recovery, the large volumes of progressive, high intensity training will fail to result in positive adaptations. Individual monitoring of athletes is an essential component to maintaining the balance between training and recovery. The first study showed that although there was good agreement between the training load (TL) prescribed by coaches and the TL executed by athletes, during sessions when a coach was not present 3 out of 6 athletes executed a higher than prescribed TL with a subsequent lower TL than prescribed during sessions when a coach was present. When looking at the group as a whole, these athletes completed 13.9% higher TL than planned during training sessions when the coach was absent, and 1.6% lower TL than planned during training sessions when the coach was present. The second study attempted to detect a threshold in TL or training monotony (M) in which athletes' subjective complaints (CI) increased significantly. Due to the proper periodization of training by the coaches, M was low and athletes were able to tolerate a high TL with low CI. The third study showed that when deliberately attempting to plan a monotonous training program, athletes tend to increase the amount of recovery time in an attempt to preserve the fine balance between training and recovery. Forty athletes were randomly assigned to either a polarized training group (PG, *n* = 21) or a monotonous training group (MG, $n = 19$). There was no significant difference between the groups for weekly TL ($p = 0.54$), M ($p = 0.24$), CI ($p = 0.7$), or weekly time trial performance ($p = 0.31$). Both groups showed a significant improvement in performance over the 11-week period. The close monitoring of athletes is a practical strategy that can be employed to respect the balance between training and recovery in an attempt to avoid overreaching and/or overtraining.

TABLE OF CONTENTS

ABSTRACT iii

LIST OF FIGURES vii

ACKNOWLEDGEMENTS viii

Chapter

1 INTRODUCTION 1

2 A COMPARISON OF ATHLETES’ AND COACHES’ RATING OF TRAINING 20

2.1 Introduction 20
2.2 Methods 23
2.3 Results 24
2.4 Discussion 34
2.5 References 36

3 TOLERABILITY OF HEAVY TRAINING LOAD AND MONOTONOUS TRAINING 38

3.1 Introduction 38
3.2 Methods 41
3.3 Results 43
3.4 Discussion 44
3.5 References 46

4 VARIATIONS IN SWIM TRAINING PATTERNS ON POSITIVE AND NEGATIVE OUTCOMES OF TRAINING 48

4.1 Introduction 48
4.2 Methods 50
4.3 Results 51

4.4 Discussion 55
4.5 References 56

5 DISCUSSION 57

LIST OF FIGURES

Figure Page

1.1. The general adaptation syndrome 3

1.2. GAS applied to athletic performance 3

1.3. Complex model of training for peak athletic performance 6

1.4. Effect of training on fitness, fatigue, and performance 11

2.1. Bland-Altman plots for training sessions with coach absent 27

2.2. Bland-Altman plots for training sessions with coach present 30

4.1. Weekly TL for polarized group (GP) and monotonous group (MG) 52

4.2. MI for polarized group (GP) and monotonous group (MG) 52

4.3. S for polarized group (GP) and monotonous group (MG) 53

4.4. CI for polarized group (GP) and monotonous group (MG) 53

4.5. Weekly TT time in seconds for polarized group (PG) and monotonous group (MG) 54

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CHAPTER 1

INTRODUCTION

In the 1930s Hans Selye proposed the general adaptation syndrome (GAS). GAS provides the theoretical basis for training modern athletes (Smith, 2003). According to GAS, physiological and psychological stressors cause systemic reactions (Selye, 1946). For example, systemic reactions occur when the body is exposed to a cold environment. Catecholamines are released into the bloodstream and initiate vasoconstriction of the peripheral blood vessels. Vasoconstriction shunts blood to the core to maintain body temperature. Plasma volume is decreased and blood pressure is increased. The body also increases its metabolic rate to initiate thermogenesis to produce heat, with lipids and carbohydrates serving as the metabolic fuels (Stocks, Taylor, Tipton, & Greenleaf, 2004). Exposure to stressors like cold cause disruptions to homeostatic equilibrium and produce the GAS Alarm stage (see Figure 1.) While some of the non-specific reactions result in damage like protein degradation and electrolyte imbalance, other specific reactions (physiologic, metabolic, etc.) allow the individual to successfully maintain body temperature in spite of the cold exposure. Although the body can respond to future stressors of the same type for a period of time, the body's resistance to other stressors or prolonged exposure to the same stressor is finite. The period of successful stress response is called the Resistance Stage. The Resistance Stage represents a new level of homeostatic equilibrium; however, as Figure 1.1 illustrates the Resistance Stage cannot continue indefinitely. At some point, and this point varies from individual to individual, continued resistance is impossible and the Exhaustion Stage is reached. When the Exhaustion Stage is reached, the body's resistance can no longer react to the stressor and the body fails.

Athletic training responses parallel GAS. To train, athletes increase the amount of weight lifted, the distance skated, or the intensity of runs. These increases in training serve as the stressors to the body. In the language of training, these stressors are called overload and result in an Alarm Stage depicted in Figure 1.2 as a temporary decrement in performance potential. The goal of training is to move the athlete through the Alarm Stage into the Resistance Stage (improved performance potential), by balancing the overload with appropriate recovery. In the Resistance Stage the athlete makes specific adaptations that increase the homeostatic equilibrium or performance potential. An increase in performance potential above the previous level is called supercompensation. The supercompensation effect is an improvement in performance. For full supercompensation to occur, recovery must be matched to the training overload (Budgett, 1998; Budgett et al., 2000; Fry, Morton, & Keast, 1991, 1992; Kentta & Hassmen, 1998). According to Kentta and Hassmen, there is little reported in the literature about the matching of recovery to overload, because there are so many potential recovery strategies and it is difficult to quantify overload and recovery. Matching recovery to overload may involve complete rest, active rest, or any number of proposed recovery techniques (Kentta & Hassmen, 1998). With adequate recovery, the athlete makes the appropriate adaptations to overload and performance increases above baseline. Because of an

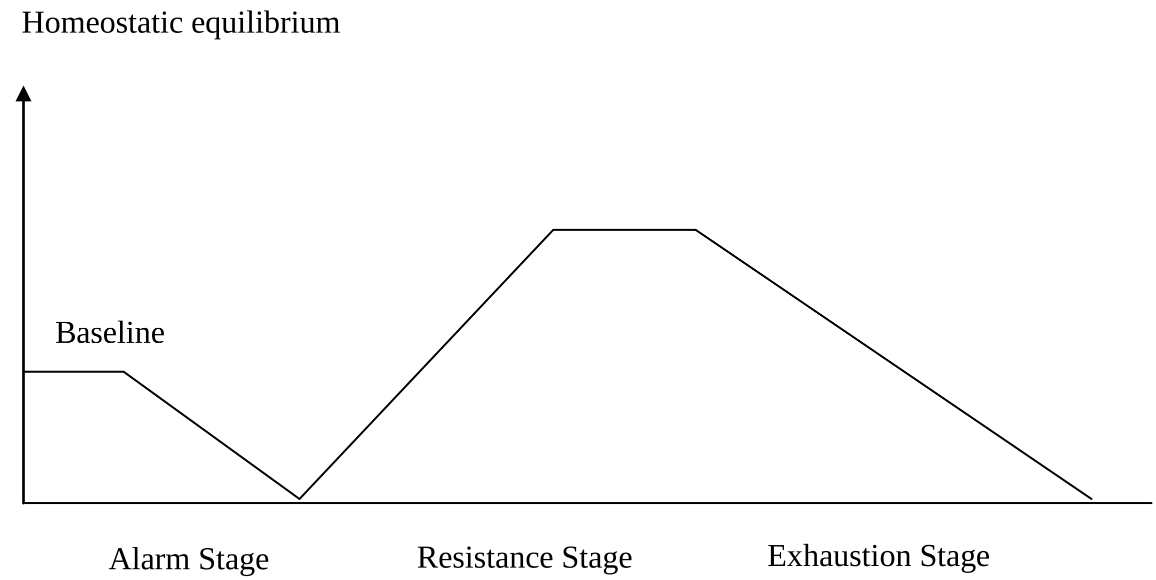

Figure 1.1 The general adaptation syndrome

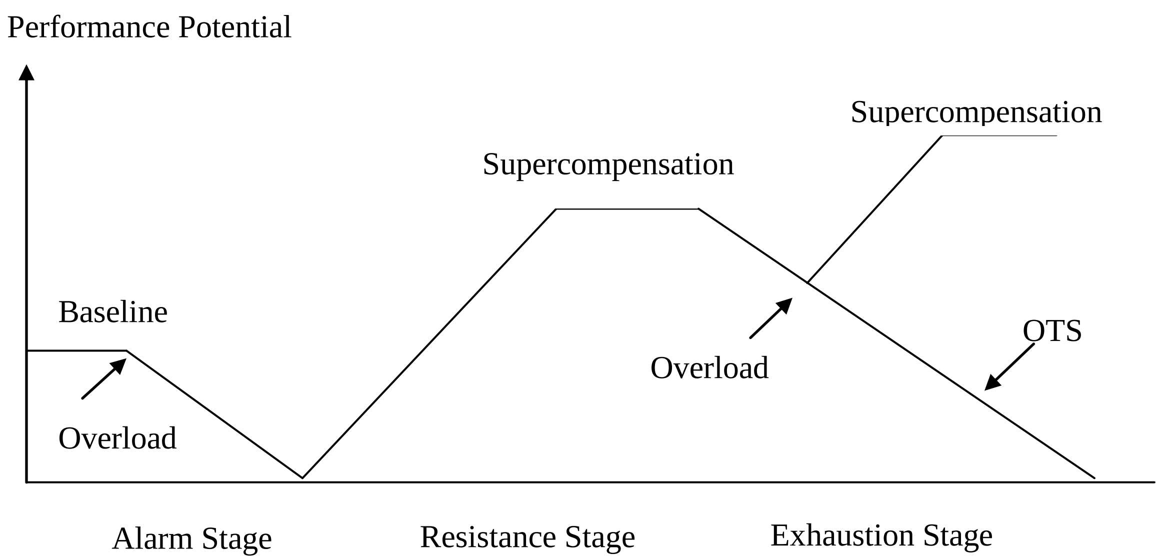

Figure 1.2. GAS applied to athletic performance

increase in performance (i.e., increased ability to lift more weight), the athlete can continue to be overloaded at progressively higher levels to cause the optimal amount of adaptation for optimal or peak performance. If recovery is inadequate, the overtraining syndrome (OTS) may occur. OTS is an example of an athlete reaching the Exhaustion Stage when the overload becomes too much for the body to handle. The body's capacity for systemic reaction to the overload becomes exhausted, decreasing the motivation and ability to continue training, and may even result in illness.

Given the detrimental consequences of OTS, coaches and sport scientists continually seek strategies for managing overload and recovery. Training periodization is such a strategy. Periodization refers to planning the systematic organization of a training season (and/or career) into smaller more manageable blocks (Bompa, 1999), including the required overload and recovery to improve performance potential. The principles of training planning originated in ancient Greece and have been refined over the years. The refinements involved in periodization focus on overloading the specific energy systems of the body (anaerobic alactic, anaerobic lactic, aerobic) at specific times, and planning recovery time to allow for adaptations to occur (Bompa, 1999). The specific energy systems of the body are overloaded at different phases of the periodization plan to increase the performance potential of the different biomotor abilities that are required for a specific sport. Different sports require differing degrees of speed, strength, and endurance, and because of athlete variability different athletes may respond in different ways to identical stressors, consequently periodization plans must be highly individualized. One athlete may recover from the overload and supercompensate quickly, whereas another athlete may require additional recovery time and/or techniques.

Periodization must take into account not only the physiological stress of training, but the psychological stress of training and life as well. To account for the physiological and psychological overload placed on the athlete, Kentta and Hassmen (1998) proposed a three step matching process to optimize recovery: a) training must be aimed at specific physiological systems of the body, b) recovery must be matched to the specific type of training stressors, and c) psychological and outside stressors must be kept to a minimum to allow the physiological systems to achieve the highest levels of adaptation.

Implementation of Kentta and Hassmen's three step process becomes complex and involves many factors. Therefore the training undertaken by athletes to improve performance should be considered multifactorial (Ericsson, Krampe, & Tesch-Romer, 1993) as well as complex, because the goal of training is to tax the appropriate system to achieve the optimal performance in a specific sport, event, or distance (Smith, 2003). Adding to the complexity of physical training is the need to account for psychological factors (work, family, money, etc.), sleep, and nutrition (Banister, Calvert, Savage, & Bach, 1975; Halson & Jeukendrup, 2004; Kentta & Hassmen, 1998). In an attempt to reduce the complexity of the training process, Figure 1.3 is used to portray the athlete as a system with several inputs and a specific output (Banister et al., 1975). The goal of Figure 1.3 is to illustrate the concept that multiple inputs to the system may affect the output.

If the training process is to be individualized, tools for monitoring training must be used, including tools for measuring training load (TL), fatigue, injury, and performance. If performance is not improving, coaches may then adjust the TL based on

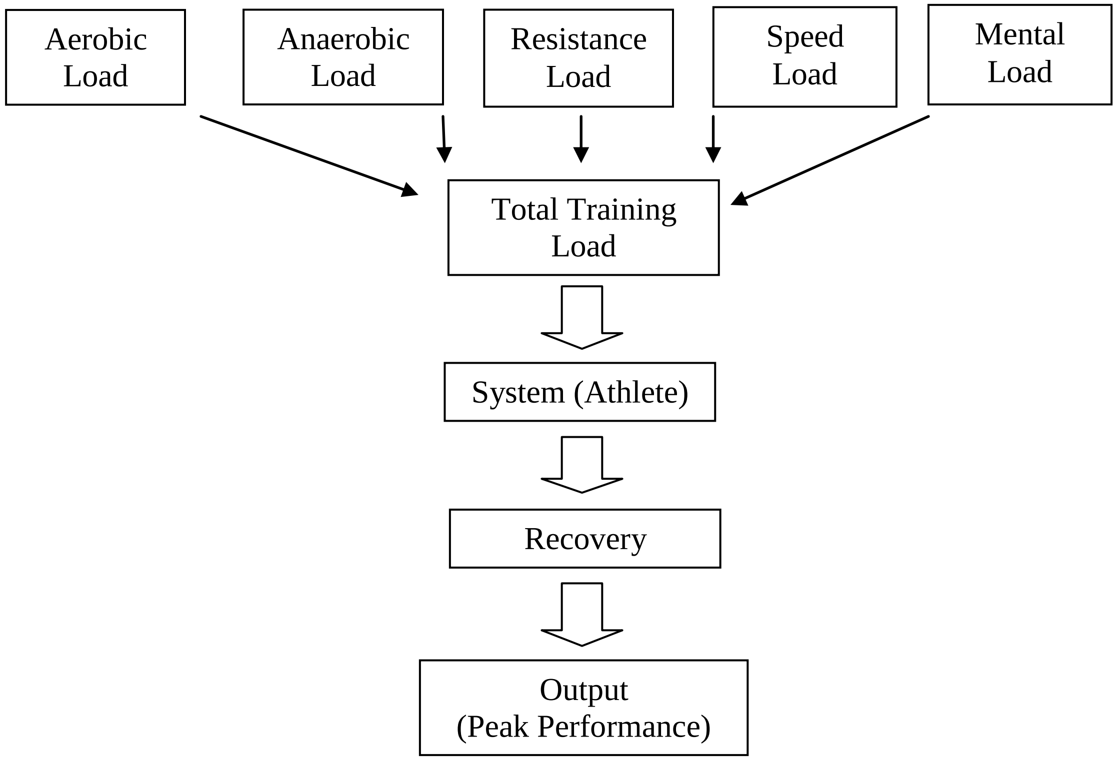

Figure 1.3. Complex model of training for peak athletic performance

the feedback they receive from the monitoring data (Banister, Carter, & Zarkadas, 1999; Bompa, 1999; Foster, Daines, Hector, Snyder, & Welsh, 1996; Foster, Daniels, & Seiler, 1999; Fry et al., 1992; Hopkins, 1991; Lehmann et al., 1991; Seiler & Kjerland, 2004; Smith, 2003). Unfortunately, the process of monitoring training can easily become unmanageable due to the vast amounts of data that might be collected to characterize the training loads and the responses to those training loads. The analysis of such significant amounts of data is nearly impossible for the coach given the many other responsibilities he/she has.

The challenge for coaches and sport scientists is to devise a system to quantify TL and recovery that is not only accurate, but practical. If the coach can collect and analyze TL data easily, the resultant information can assist coaches and athletes in the planning and assessing of training programs so that athletes can maximize their performance potential (Hopkins, 1991). Hopkins has suggested several methods of obtaining training data, including collecting retrospective data (questionnaires, etc.), monitoring physiological variables during training (i.e., heart rate, lactate, etc.), and collecting current performance-related data (i.e., mileage run, lap times, power output, etc.).

One early training monitoring system that has capitalized on the suggestions of Hopkins in collecting training data is the training impulse (TRIMP). TRIMP is a method of quantifying TL by combining a measure of intensity and duration of the training session (Banister et al., 1975). The goal of combining training intensity and duration into one variable, the TRIMP, is to provide a gestalt view of the training stress placed on the athlete. First developed by Banister et al., the TRIMP used the product of the training distance and an arbitrarily designated intensity unit (1 = easy work, 2 = harder intensity-long duration, 3 = quality training, speed work). For example, a swimmer whose workout consisted of swimming 1000 meters at an easy pace would amass a TRIMP of 1000 units (1000m * 1 intensity unit = TRIMP of 1000). With the development of relatively inexpensive heart rate (HR) monitors, the TRIMP was adapted to become the product of training duration and HR during the training segment (Morton, Fitz-Clarke, & Banister, 1990). HR could be recorded for each minute of the training session. Given the capacity of the HR monitors to record HR on a minute-by-minute basis, the use of HR data for TRIMP calculation quickly became complex and time consuming to analyze due to the vast amounts of data that were collected during each training session.

The modified TRIMP (mTRIMP) method proposed by Foster is a simplification of the TRIMP. Like the TRIMP, mTRIMP TL is quantified by calculating the product of training session duration (minutes) and session rating of perceived exertion (SRPE). In the mTRIMP, SRPE is a surrogate for the HR that was used in the Banister TRIMP model (Foster, 1998). The Borg Category Ratio RPE 10 point scale was developed as a modification of Borg's 15-point RPE scale to quantify the nonlinear increase in effort with increasing intensity (Borg, 1998). It is thought that the perceived exertion is influenced by many underlying physiological stimuli, including both central (HR, minute ventilation, oxygen uptake, and respiratory rate) and peripheral factors (blood lactate, blood pH, mechanical strain, temperature, and substrate availability) that are integrated by the brain (Hampson et al., 2001). The use of the Category Ratio RPE scale gives an indication of both the external and internal stress that training places on the body. By using SRPE, Foster et al. proposed physiological and psychological inputs could be integrated providing meaningful information to the coach about the athlete's response to the entire training session, not just specific segments. The quantification of TL for a given session allows compilation of TL data over days, weeks, and even years for each individual athlete in a much more efficient manner than grappling with the tremendous amount of data amassed from minute by minute recordings of HR during a training session. The mTRIMP method also allows coaches to quantify a TL for training sessions employing different modalities of training (i.e., swimming, resistance training, and running) in a very practical manner (Foster, Florhaug, et al., 2001; McGuigan & Foster, 2004).

The mTRIMP methodology, because of its simplicity, also provides an opportunity to monitor and compare training plans with actual training. If a coach plans for athletes to have a 90 minute training session at an SRPE of 8, the planned TL would be 720 mTRIMP units. If an athlete reports a TL of 810 mTRIMP units (90 minutes * 9 SRPE = 810 mTRIMP units), it becomes immediately apparent that there is a mismatch between the planned TL and the actual TL. By making such comparisons, coaches have a tool for getting a sense of the TL an individual athlete can handle. If in addition to tracking planned and actual TLs, athlete performance is also tracked, the coach will have a tool for determining what TLs result in the best possible performance for a given athlete. Thus, monitoring planned TL, actual TL, and performance makes for another valuable tool for planning future training programs for individual athletes. When close attention is paid to the data derived from monitoring, one can get a sense of how that athlete is responding to the training. A study examining the effect of increased TL on performance showed that an increase in total TL and intensity may be associated with up to a 10% improvement in performance (Foster, Daines, Hector, Snyder, & Welsh, 1996). Using the mTRIMP method to quantify TL, Foster et al. showed a significant increase in TL over 6 weeks from 1242 units to 1386 units, and a significant increase in RPE of training sessions from 3.8 to 4.0. Performance, assessed by a standard time trial, also improved significantly from 12.95 minutes to 12.66 minutes. These data support the hypothesis that the mTRIMP approach can provide athletes and coaches with valuable insights for evaluating training.

Banister et al. have suggested that two variables, fitness and fatigue, may provide even more data for monitoring individual athletes' response to training. According to

Banister et al., training produces two opposing effects on the body. There is a positive component that promotes the adaptations necessary for improving performance, referred to as fitness. There is also a negative component that tends to cause a decline in performance, referred to as fatigue. Each of these components has a time frame in which their effects are noticeable (Banister & Calvert, 1980). The negative effects of fatigue are initially larger than the positive effects of fitness, but tend to decay more rapidly (Banister et al., 1975). Approximately 15 days following a training session, fatigue is back to baseline (Fitz-Clarke, Morton, & Banister, 1991). The effects of fitness are not as high initially, but last approximately 45 days (Fitz-Clarke et al., 1991). Figure 1.4 shows a long-term pattern of the effect of training on fitness, fatigue, and performance. The time constants for fitness and fatigue can be determined for individual athletes through a modeling process. These time constants are very individual and likely vary from sport to sport depending on the energetic requirements. As training progresses, the additive effects of subsequent training sessions will dictate the Fitness and Fatigue levels of the athlete. Tracking fitness and fatigue can give an indication of when an athlete may have their optimal performance (Figure 1.4). When the difference between fitness and fatigue is high (indicating a high level of fitness and a low level of fatigue) the athlete should experience their best performance (Busso, Candau, & Lacour, 1994; Fitz-Clarke et al., 1991).

Due to the time course of the body’s response to training and our inclination of operating on the natural rhythm of a week, Foster has suggested using a 6-week rolling average of TL to calculate fitness and a 1-week rolling average of TL to calculate fatigue

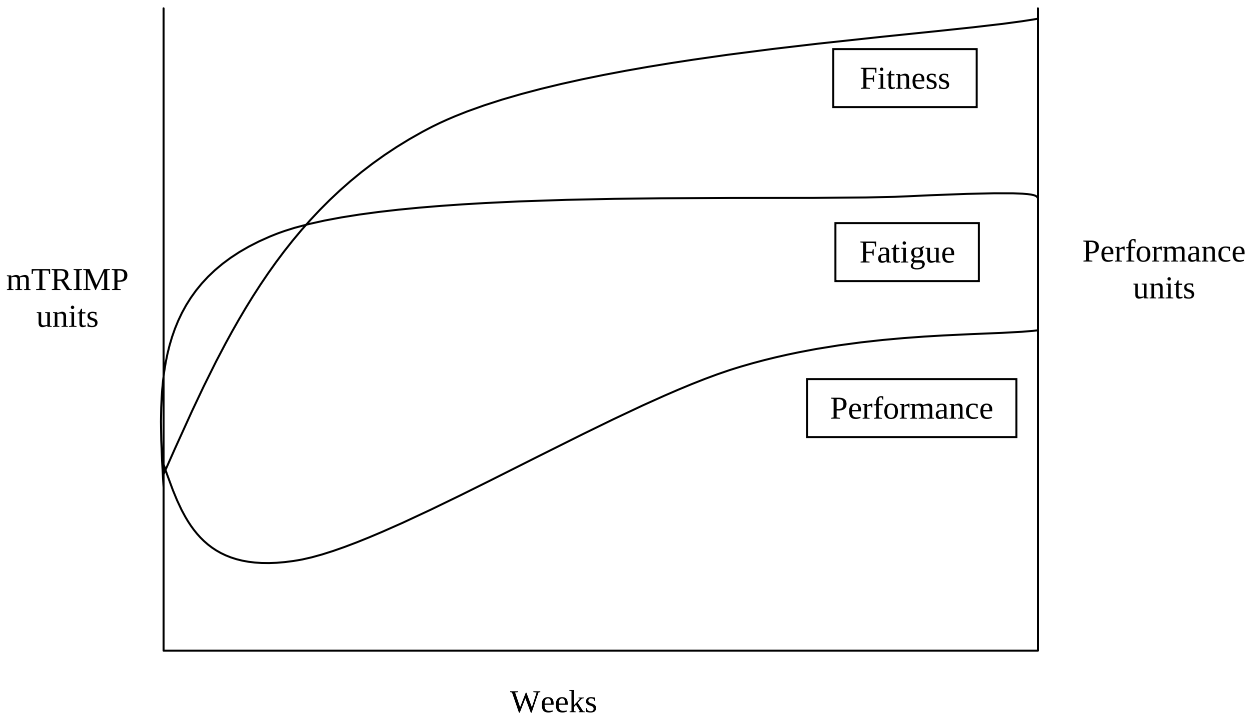

Figure 1.4. Effect of training on fitness, fatigue, and performance

(C. Foster, personal communication, October 27, 2010) versus Banister's use of 45 days to account for fitness and 15 days to account for fatigue. This simple calculation falls in line with Foster's replacement of HR with SRPE in the calculation of TL, and represents a practical strategy for athlete monitoring.

In addition to the strategy of using fitness and fatigue to monitor the effects of training on the performance of athletes, Foster (1998) has proposed using an index of variability to evaluate the training experienced by athletes. Bruin et al. (1994) first realized the deleterious effect that training at the same intensity daily, or monotonous training, had on horses involved in an endurance training program. Horses that were subjected to increasing TLs improved their performance when training followed a hard day-easy day program, and TL on the hard days was increased but intensity was not incremented upward on the easy days. Conversely, when TL was increased by increasing intensity on the easy days so that each training day became similar or monotonous, the horses began to exhibit decreased performance as well as symptoms similar to the overtraining syndrome seen in humans (Bruin, Kuipers, Keizer, & Vandervuisse, 1994). Foster and Lehmann have suggested that the combination of TL and training monotony are responsible for the strain experienced by an athlete that may lead to decreased performance, illness, and lethargy; otherwise known as the overtraining syndrome (Foster & Lehmann, 1997). Using the mTRIMP system, the monotony index (M) is calculated as the daily mean TL divided by the standard deviation of TL over a 1-week period. The strain (S) an athlete experiences during training is calculated as the product of TL and M. It is thought that when an athlete trains above their individual threshold of TL, M, and S, negative adaptations will supersede positive adaptations of training and performance will decrease (Foster, 1998). Foster showed that in 25 competitive athletes, 84% of illnesses were attributed to an increase in TL above an athlete's individual training threshold. Training above individual thresholds for M and S also accounted for 77% and 89% of illnesses, respectively. These data support the notion that individual athletes have thresholds of training that when monitored and controlled may protect athletes from the negative effects of training.

Although coaches design training plans with currently available scientific information, athletes may not always follow that training plan (Foster, Heimann, Esten, Brice, & Porcari, 2001; Stewart & Hopkins, 1997). If athletes are executing a higher TL than the coach planned, or are creating a pattern of monotonous training, a lack of recovery may lead to a decrease in performance (Foster, 1998). Because a small decrease in performance (1-2%) can mean the difference between first and fifth, athletes and coaches often react to a decrease in performance by increasing TL even further. This decreased performance with increased TL is often described as the overtraining syndrome (OTS). OTS is actually a continuum with short-term effects (temporary decrease in performance) called overreaching and long-term effects (extended decrease in performance) called overtraining (Halson & Jeukendrup, 2004). There are many physiological (decreased performance, increased resting HR, fatigue, muscle aches and pains, decreased submaximal lactate production), biochemical (increased cortisol, decreased testosterone, suppressed immune parameters, decreased iron/ferritin, decreased hemoglobin), and psychological (mood changes, lethargy, irritability, reluctance to train/compete) signs and symptoms associated with the OTS continuum (Angeli, Minetto, Dovio, & Paccotti, 2004; Budgett, 1998; Budgett et al., 2000; Coutts, Wallace, & Slattery, 2006; Fry et al., 1991; Gleeson, 2002; Halson & Jeukendrup, 2004; Hooper, Mackinnon, Howard, Gordon, & Bachmann, 1995; Kentta & Hassmen, 1998; Kuipers & Keizer, 1988; Lehmann, Foster, & Keul, 1993; Rietjens et al., 2005; Urhausen, Gabriel, Weiler, & Kindermann, 1998; Urhausen & Kindermann, 2002). The signs and symptoms are not universal, which makes it difficult to determine where on the continuum the athlete lies. The variability in symptoms has also made it difficult to generate and test hypotheses governing the mechanisms underlying OTS. In spite of the numerous equivocal results in studies designed to identify OTS mechanisms, the epidemiological data support the conclusion that OTS is a common problem, affecting 5-20% of athletes, depending on the sport (Halson & Jeukendrup, 2004).

Faced with the challenge of preventing OTS without complete understanding of the underlying mechanisms, coaches and sport scientists have sought to identify practical strategies for managing TL and recovery to identify athletes in the early stages of overreaching, before overtraining is reached. The mTRIMP in combination with other athlete derived variables has therefore been proposed as a tool for the early identification of overreaching. Some of the athlete derived variables include subjective measures of mental well-being, muscle aches and pains, and sleep and nutrition status.

Summary

Optimal performance is not possible without optimal training and the designing of optimal training is dependent upon monitoring individual athlete responses to training; however, the task of monitoring training loads and individual athlete responses to those loads could easily become expensive and burdensome to the coach. Fortunately practical training and athlete monitoring strategies have been evolving. Through extensive literature review, we know several aspects of the relationship between training and performance: a) optimal training is best accomplished by monitoring individual athlete responses; b) mTRIMP is a practical method to monitor athletes; c) initial evidence is in support of mTRIMP as a valid and reliable tool; d) mTRIMP can be used to calculate fitness and fatigue; and e) mTRIMP can also be used to identify monotonous training.

Although coaches and sport scientists have been gathering data in support of the use of mTRIMP as a way of monitoring individual athletes response to training, more research is needed to examine the use of mTRIMP with different athlete populations (level of competition, types of sport, etc.) and different training circumstances (coach supervised and non-supervised, planned monotony versus polarized training). Therefore, the purpose of the following studies is to assess the practicality and value of using the mTRIMP system to examine the periodization process and to detect overreaching in its earliest stages.

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CHAPTER 2

A COMPARISON OF ATHLETES' AND COACHES' RATING OF TRAINING

Introduction

The training undertaken by athletes to improve performance is a complex process. Much of the complexity stems from the need for the proper physiological systems being taxed, but with the requirement of adequate recovery time to achieve the optimal performance for each specific sport, event, or distance (Smith, 2003). Without adequate recovery the large volumes of progressive, high intensity training will fail to result in positive adaptations (Smith, 2003). Consequently, there is a fine balance between the amount of training that leads to positive adaptations and the amount that leads to negative adaptations. To achieve this balance between training and recovery each athlete must be followed or monitored individually. Monitoring athletes' training loads and responses to training allows for the possibility of adjustments being made in the training plan when the athlete is not making positive adaptations. Thus, long-term monitoring of an athlete's entire season allows coaches not only to plan the appropriate training program for each individual athlete but to adapt the training depending on the athlete's response to training.

When monitoring athletes, it is crucial to have a means of quantifying the training load (TL), as well as a means for quantifying the athlete response. The process of quantification can assist coaches and athletes in the planning of training and the assessment of training responses (Hopkins, 1991). Depending on the sport, TL can be determined by the volume (distance covered or hours accumulated) of training and the intensity of training. The training impulse (TRIMP) is a method of determining TL that combines the effects of duration and intensity of the training session (Banister, Calver, Savage, & Bach, 1975). First developed by Banister et al. (1975), the TRIMP used the product of the training distance and an arbitrarily designated intensity unit (1 = easy work, 2 = harder intensity-long duration, 3 = quality training, speed work) to quantify the training load. Later a TRIMP score was designated as the product of training duration and percent heart rate reserve (% HRR) multiplied by a constant during the training session (Morton, Fitz-Clark, & Banister, 1990). The training quantification method developed by Foster (1995, 1998) is a modification of the TRIMP (mTRIMP), and designates TL as the product of session duration and session rating of perceived exertion (SRPE) (Foster, Hector, Welsh, Schrager, Green, & Snyder, 1995; Foster, 1998). The mTRIMP allows for TL to be quantified by the session, day, week, or longer for each individual athlete in a manner that is simpler than that of Banister et al. (1975). This method has been validated when compared to the % HRR TRIMP method (Foster, Florhaug, Franklin, Gottschall, Hrovatin, Parker, Doleshal, & Dodge, 2001).

Previous research has shown that although coaches carefully quantify training plans for their athletes, athletes do not always execute that plan (Foster, Heimann, Esten, Brice, & Porcari, 2001). According to Foster et al. (2001), some athletes may train hard on coach-planned easy days, therefore increasing the TL. If an athlete is training harder than planned, a lack of adequate recovery may lead to the inability to train as hard as desired on coach-planned hard days. Over a period of time, a lack of recovery can lead to a state of decreased performance which, if transient, is known as overreaching, and if quasi-permanent is known as overtraining syndrome (OTS) (Kuipers & Keizer, 1988). The incidence of OTS among athletes can be quite high, occurring in 5-20% of athletes depending on the sport (Halson & Jeukendrup, 2004). OTS may lie on a continuum, with overreaching being considered short-term performance decrements and overtraining being considered long-term performance decrements (Halson & Jeukendrup, 2004). It is fairly well established that overreaching and OTS are more a function of failure to recover properly than of training too heavy on the hard days (Bruin, Kuipers, Keizer, & Vander Vusse, 1994). If an athlete does not allow for adequate recovery the state of underperformance may last weeks, months, or years, possibly robbing an athlete of his/her career (Budgett, Newsholme, Lehmann, Sharp, Jones, Peto, Collins, Nerurkar, & White, 2000). Therefore, it is extremely important to use valid techniques to monitor athletes to ensure they are following the training plan. It is also important to identify training situations in which athletes may be likely to deviate from the planned training load, such as sessions when the coach is not present.

The purpose of this study was to examine the influence of the coach being present or absent on the agreement between the planned mTRIMP and the actual mTRIMP training loads of elite long track speed skaters. We hypothesized that there would be better agreement between the planned and actual training loads during those sessions when the coach was present.

Methods

*Participant selection***.** Archive data that included TL information from 3 male and 3 female elite long track speed skaters (including 2 Olympians and 1 Olympic medalist) and the TL that was planned by the coaches was used to examine the influence of coach presence on the level of agreement between the planned and actual TL. Athletes with complete TL records for the Preparation Phase (PP) of the season were used for analysis. The speed skaters ranged in age from 20-30 at the time of data collection. Each athlete met the specific selection criteria required to be selected to the U.S. National Speed Skating Team, including time standards and results from previous seasons.

*Procedures***.** Elite long track speed skaters training with the U.S. National Team began training with the team in May. This period of the season is known as the Preparation Phase (PP), and included training sessions that were long in duration and/or difficult in intensity. During the PP the coach provided the athletes with a specific training program that included the type of training (i.e., cycling, skating, weight training), duration of training (minutes), and intensity of training (RPE). From this training plan, the planned TL was calculated. The coaches followed a typical periodization plan of training with relatively easier training days following relatively harder training days and a two hard week-one easy week overall pattern. The coaches were typically present for the more difficult and/or technical training sessions, but allowed the athletes to train on their own for some of the relatively easier training sessions. During the PP, training typically occurred once or twice a day, 6 days of the week. The U.S. National Team athletes were required to report their training information on a session by session basis to the coach or sport scientist. Athletes reported the duration of the training session (in minutes) and the session intensity based on the Category Ratio Rating of Perceived Exertion (SRPE) scale (Foster et al., 1995). The TL planned by the coaches and the TL executed by the athletes were calculated as the product of the session duration (minutes) and the SRPE. This resulted in a dimensionless number that was used for analysis.

Statistical methods. Bland-Altman plots (Bland &Altman, 1986) were used to determine the extent of the agreement between the planned TL of coaches and the actual TL for each individual athlete. Separate Bland-Altman plots were used for sessions when the coach was present and sessions when the coach was absent. Agreement was based on the following criteria: a) mean difference score between the actual TL and the planned TL close to zero; b) points on the Bland-Altman plots falling within the upper and lower limits of ± 2 standard deviations (SD) of the mean difference score; and c) mean difference TL scores are not significantly correlated with planned TL scores. Significance for Pearson product-moment correlations was set at ≤ 0.05.

Results

For Athlete 1 during training sessions when the coach was absent ($n = 18$), the mean difference between the actual TL and the planned TL was 18.55 (+7.37%). All points but one were within ± 2 SD of the mean difference score. There was a weak, non-significant correlation between the mean difference score and the planned TL ($r = 0.16$, $p = 0.53$; see Figure 2.1). During training sessions when the coach was present ($n = 55$), the mean difference between the actual TL and planned TL was 134.73 (+14.68%). All points but one were within ± 2 SD of the mean difference score (see Figure 2.2). There was a weak, non-significant correlation between the mean difference score and the planned TL ($r = -0.22$, $p = 0.11$; see Figure 2.2).

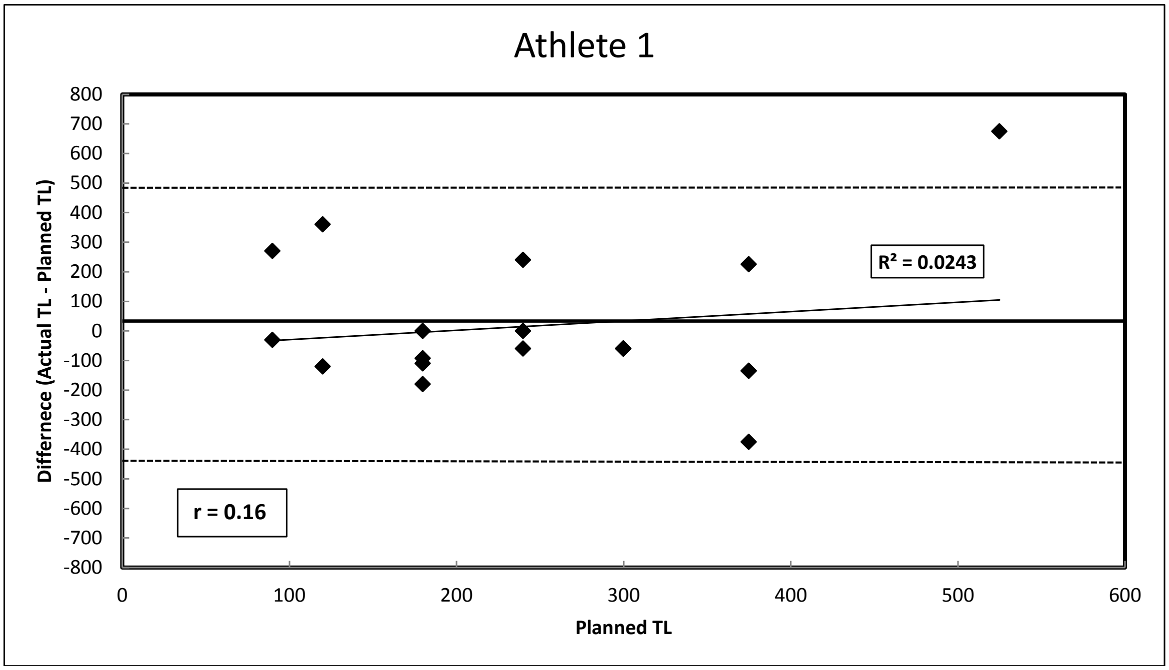
For Athlete 2 during training sessions when the coach was absent (*n* = 13), the mean difference between the actual TL and the planned TL was 6.79 (+2.91%). All points but one were within ± 2 SD of the mean difference score. There was a weak, non-significant correlation between the mean difference score and the planned TL ($r = -0.24$, $p = 0.43$; see Figure 2.1). During training sessions when the coach was present (*n* = 40), the mean difference between the actual TL and planned TL was -193.90 (-20.59%). All points but two were within ± 2 SD of the mean difference score. There was a moderate, significant correlation between the mean difference score and the planned TL ($r = -0.38$, $p = 0.02$; see Figure 2.2).

For Athlete 3 during training sessions when the coach was absent (*n* = 11), the mean difference between the actual TL and the planned TL was 127.92 (+56.23%). All points were within ± 2 SD of the mean difference score. There was a strong, significant correlation between the mean difference score and the planned TL ($r = 0.71$, $p = 0.01$; see Figure 2.1). During training sessions when the coach was present (*n* = 42), the mean difference between the actual TL and planned TL was -115.87 (-12.07%). All points but four were within ± 2 SD of the mean difference score. There was a strong, significant correlation between the mean difference score and the planned TL ($r = -0.57$, $p = 0.00008$; see Figure 2.2).

For Athlete 4 during training sessions when the coach was absent (*n* = 13), the mean difference between the actual TL and the planned TL was -0.54 (-0.21%). All points but one were within ± 2 SD of the mean difference score. There was a weak, non-significant correlation between the mean difference score and the planned TL ($r = 0.10$, $p = 0.75$; see Figure 2.1). During training sessions when the coach was present (*n* = 41), the mean difference between the actual TL and planned TL was 91.25 (+10.00%). All points but three were within ± 2 SD of the mean difference score. There was a weak, non-significant correlation between the mean difference score and the planned TL (r = -0.17, p = 0.29; see Figure 2.2).

For Athlete 5 during training sessions when the coach was absent (n = 15), the mean difference between the actual TL and the planned TL was 20.94 (9.88%). All points but one were within ± 2 SD of the mean difference score. There was a weak, non-significant correlation between the mean difference score and the planned TL (r = -0.28, p = 0.31; see Figure 2.1). During training sessions when the coach was present (n = 53), the mean difference between the actual TL and planned TL was 0.74 (+0.08%). All points but four were within ± 2 SD of the mean difference score. There was a strong, significant correlation between the mean difference score and the planned TL (r = -0.52, p = 0.00006; see Figure 2.2).

For Athlete 6 during training sessions when the coach was absent (n = 20), the mean difference between the actual TL and the planned TL was 20.36 (+8.51%). All points were within ± 2 SD of the mean difference score. There was a very weak, non-significant correlation between the mean difference score and the planned TL (r = -0.05, p = 0.83; see Figure 2.1). During training sessions when the coach was present (n = 55), the mean difference between the actual TL and planned TL was -7.23 (-0.79%). All points but five were within ± 2 SD of the mean difference score. There was a weak, significant correlation between the mean difference score and the planned TL (r = -0.28, p = 0.04; see Figure 2.2).



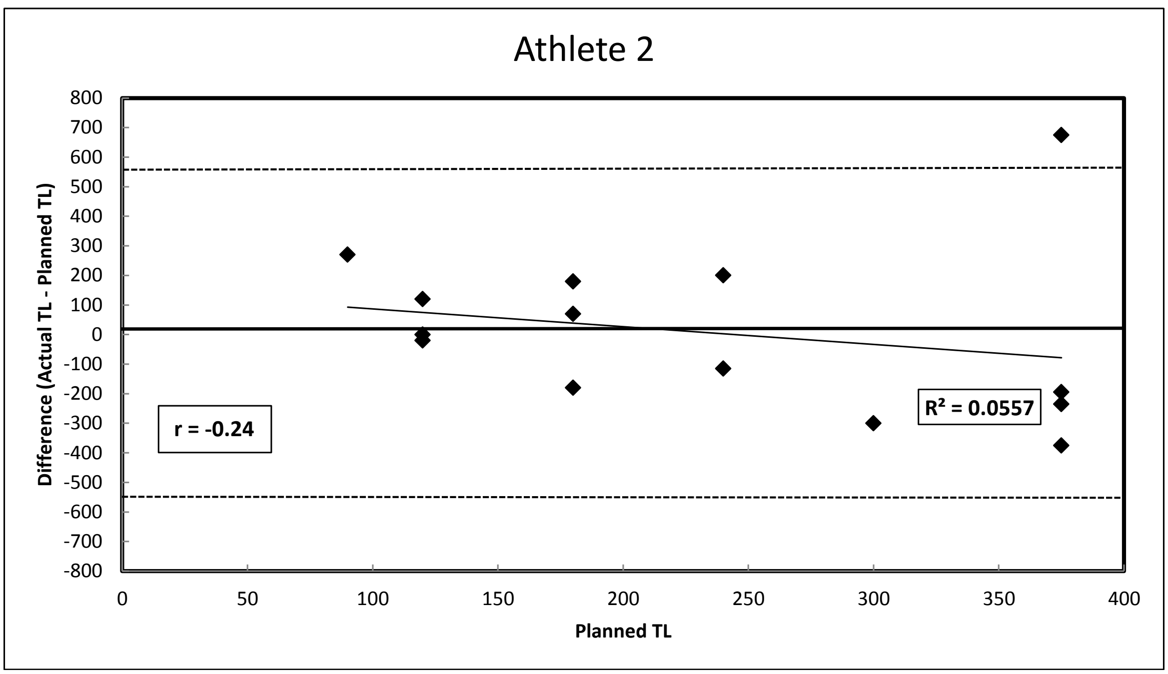
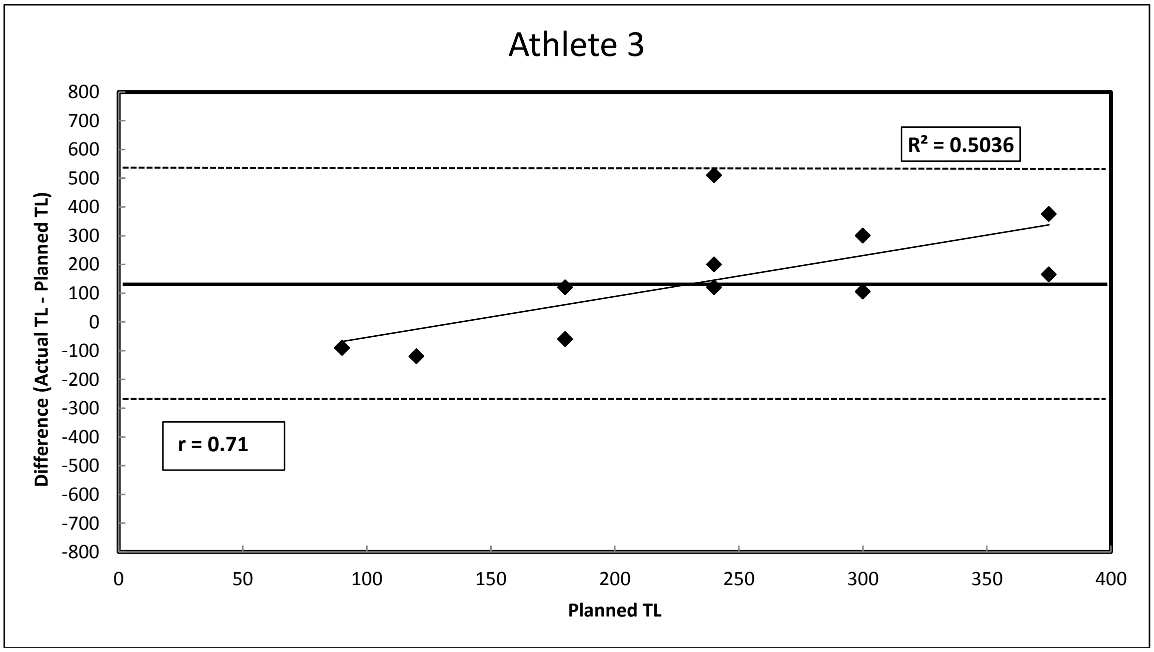
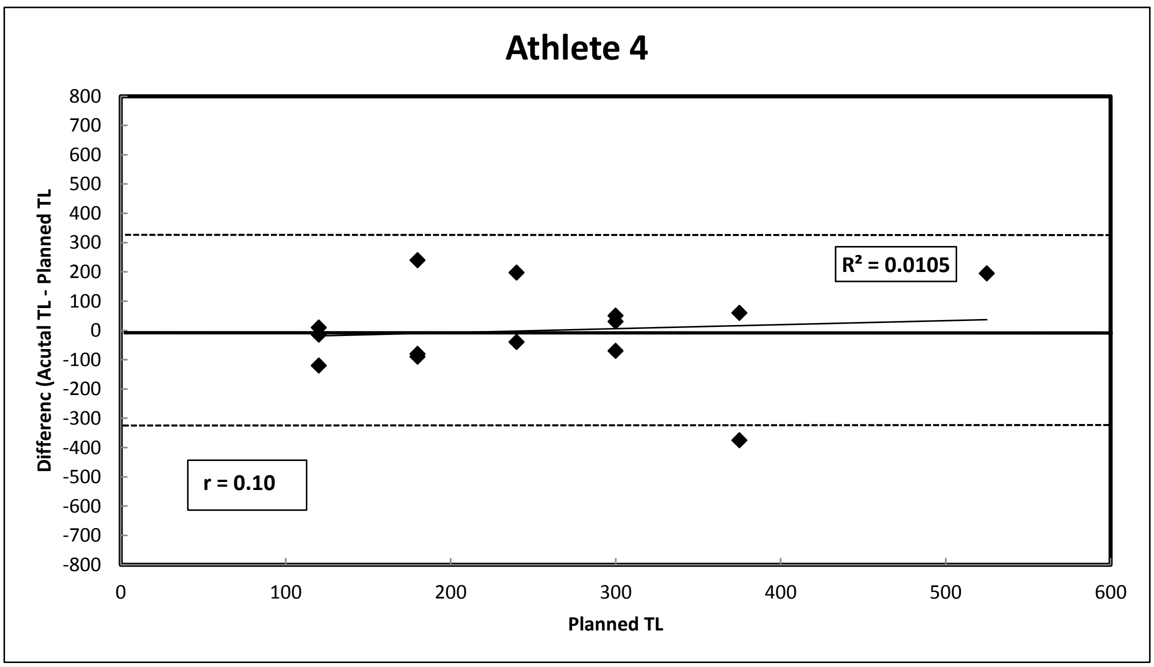


Figure 2.1. Bland-Altman plots for training sessions with coach absent





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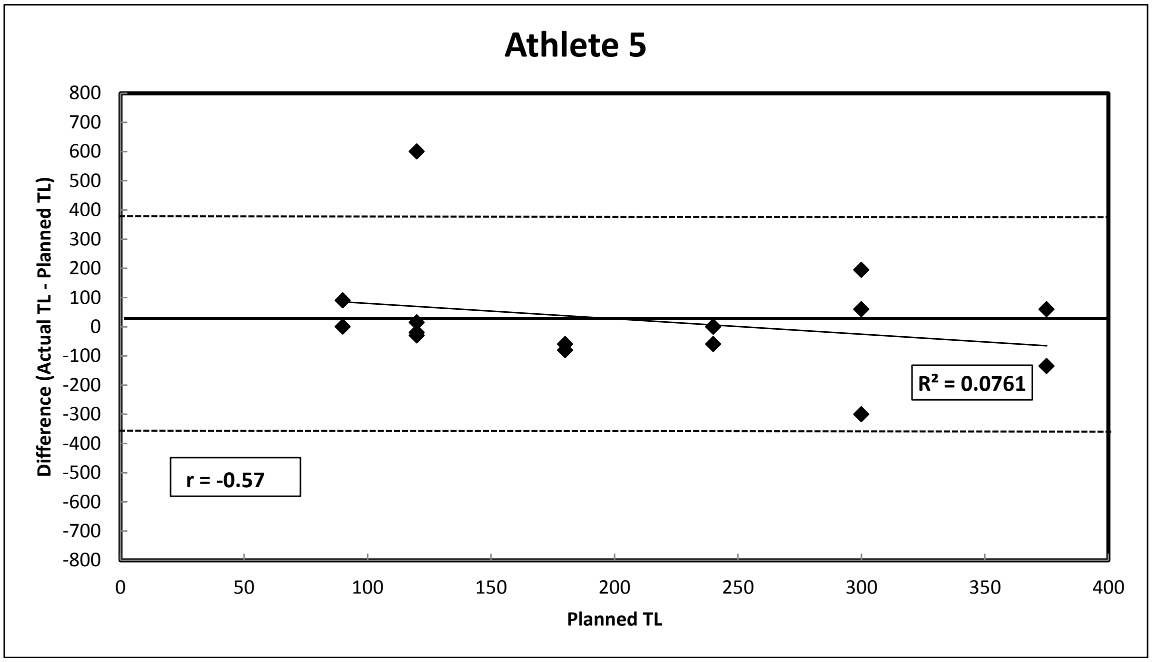


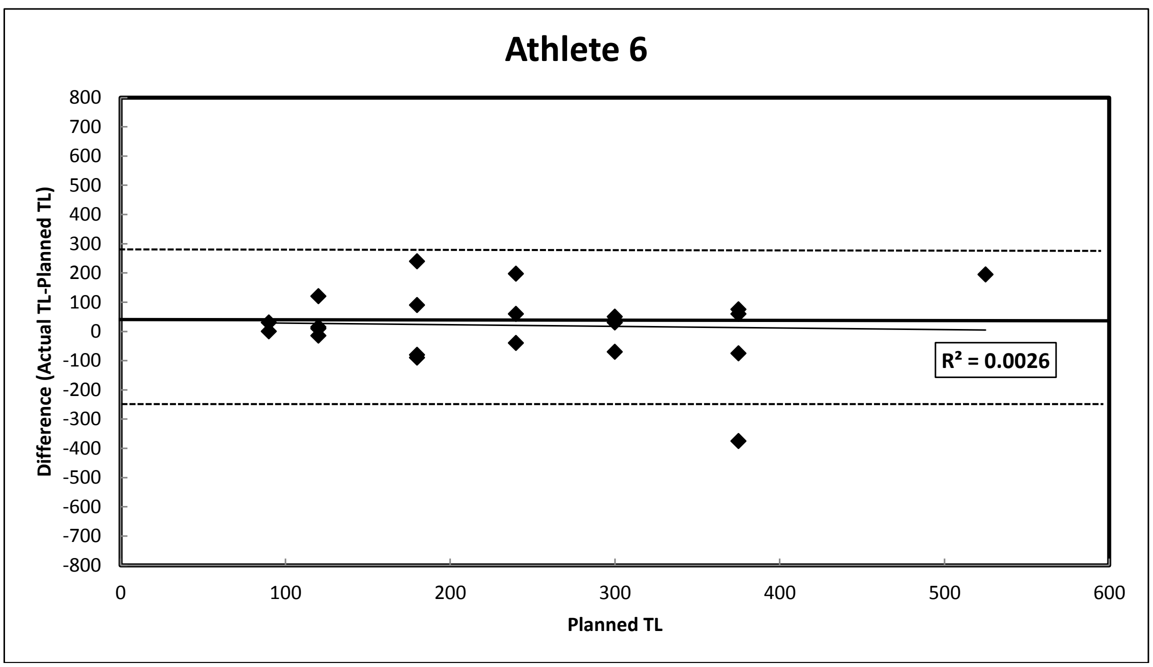


Figure 2.1 cont.

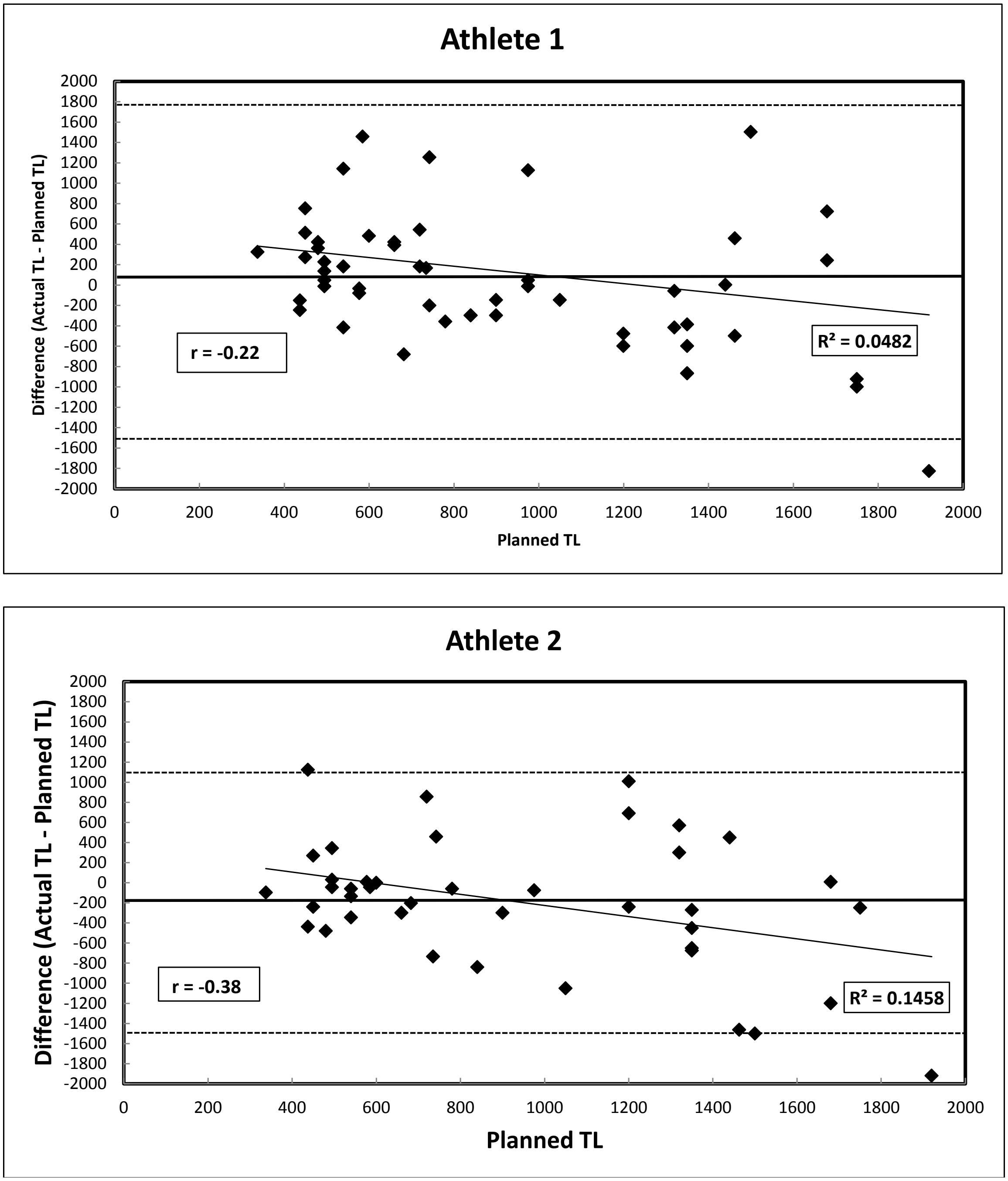
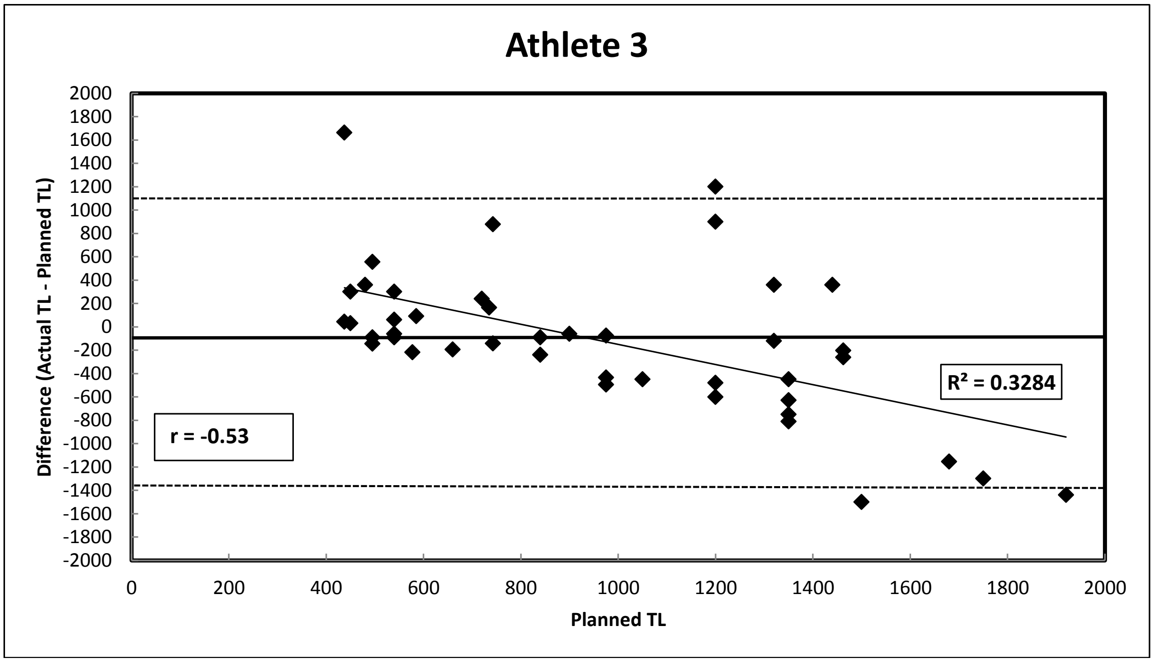


Figure 2.2. Bland-Altman plots for training sessions with coach present



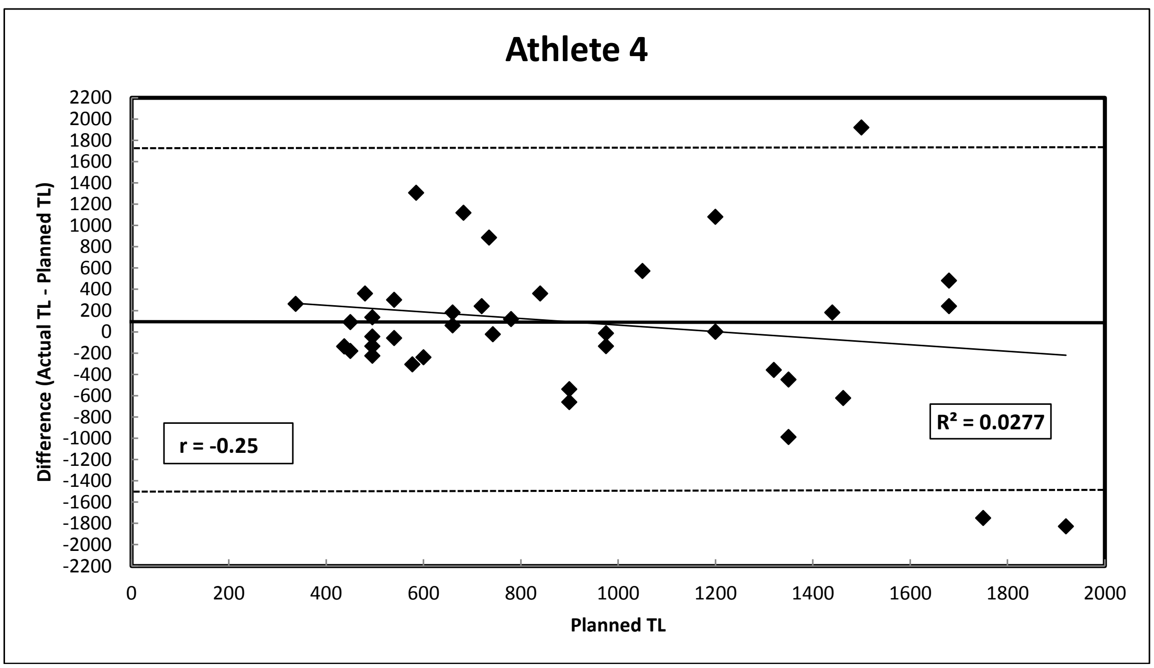
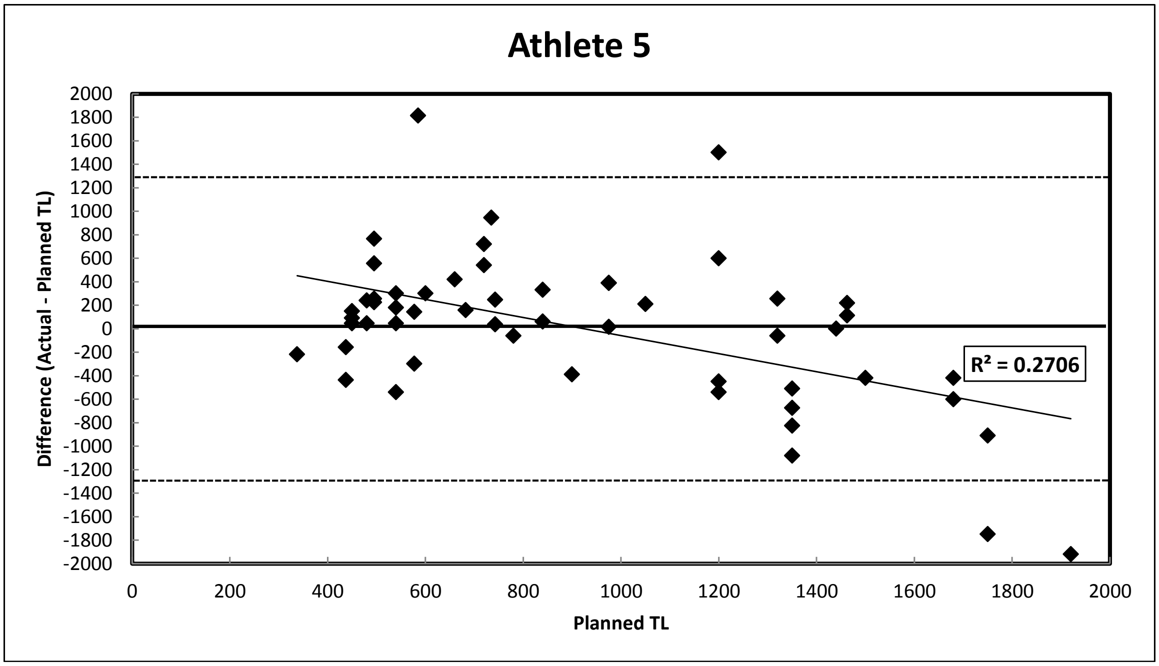


Figure 2.2 cont.



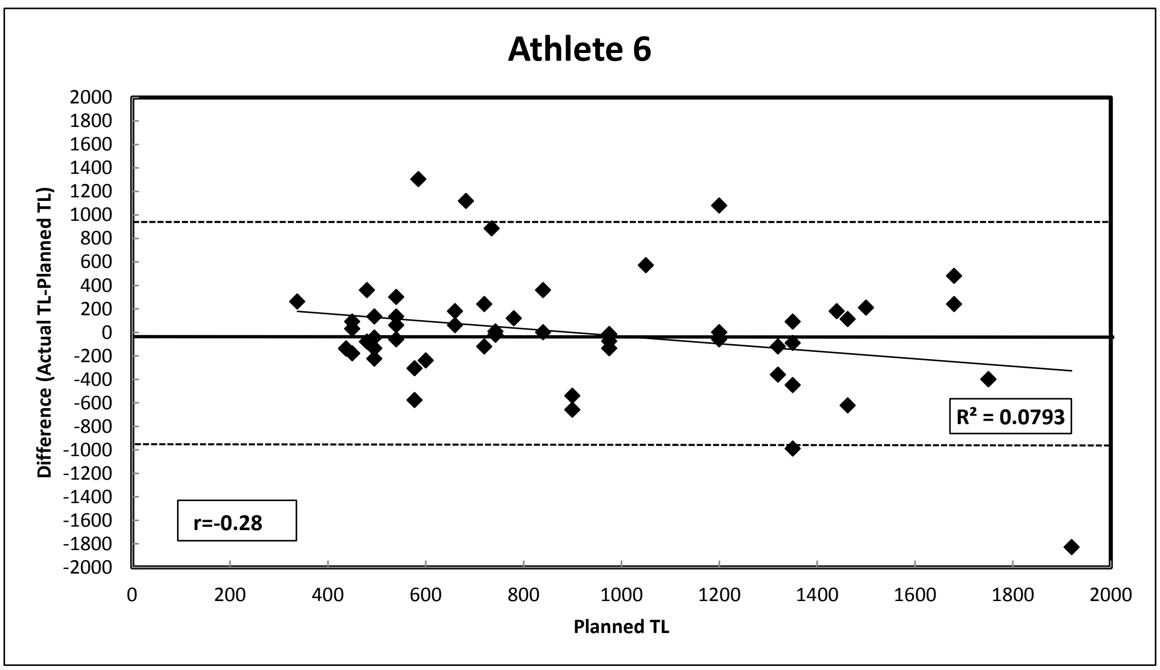


Figure 2.2 cont.

When comparing the group as a whole, there was no significant difference between the actual TL (269 ± 45) and the planned TL (236 ± 16) when the coach was absent ($p = 0.12$), or between the actual TL (913 ± 109) and the planned TL (929 ± 18) when the coach was present ($p = 0.75$).

Table 2.1 shows which athletes met the specified criteria for agreement between the actual TL and planned TL for sessions when the coach was absent. Criteria for the mean difference score close to zero were met if the mean difference score was within ± 5% of the planned TL. Criteria for points being within ± 2 SD of the mean difference score were met if ≤ 2 points fell outside of ± 2 SD. Criteria for non-significant correlations between mean difference scores and planned TL were met if $p > 0.05$.

Table 2.2 shows which athletes met the specified criteria for agreement between the actual TL and planned TL for sessions when the coach was present. Criteria for the mean difference score close to zero were met if the mean difference score was within ± 5% of the planned TL. Criteria for points being within ± 2 SD of the mean difference score were met if ≤ 5 points fell outside of ± 2 SD. Criteria for non-significant correlations between mean difference scores and planned TL were met if $p > 0.05$.

Table 2.1 Athletes meeting set criteria when coach was absent from training session

Athlete	Mean Difference Score	± 2 SD	Non-Significant Correlation
1		x	x
2	x	x	x
3		x	
4	x	x	x
5		x	x
6		x	x

Table 2.2 Athletes meeting set criteria when coach was present at training session

Athlete	Mean Difference Score	± 2 SD	Non-significant Correlation
1		x	x
2		x	
3		x	
4		x	x
5	x	x	
6	x	x	

Discussion

Coaches carefully plan training programs for athletes with the goal of improving performance, while preventing OTS. Most coaches assume that athletes execute the planned training, although previous research has shown that this is not always the case (Foster et al., 2001). A mismatch in the planned and executed TL may lead to an imbalance in recovery and possibly overreaching and/or OTS.

Our study aimed to assess the influence of coach presence or absence on the agreement between the planned TL and the actual TL. Our results show that most of these elite level speed skaters met two out of the three criteria for agreement between planned TL and actual TL, indicating that these athletes typically followed the training plan designed by the coach.

Although overall there was not a significant difference in agreement between planned TL and actual TL during training sessions when a coach was absent versus present, three out of six athletes executed a higher TL than planned during coach absent training sessions, with a subsequently lower TL than planned during coach present training sessions. It is supposed that if athletes are training either longer or more intensely on coach-intended easy days, that coach-intended hard days may be compromised and training may become more monotonous with little variability from day to day. Conversely, two athletes executed a higher TL than planned during sessions when a coach was both absent and present. This increase in overall TL may disrupt the balance between recovery and training and may lead to overreaching and/or OTS. When looking at the group as a whole, these athletes completed 13.9% higher TL than planned during training sessions when the coach was absent, and 1.6% lower TL than planned during training sessions when the coach was present. This mismatch in planned and actual TL, if extended for a long period of time, may upset the fine balance between training and recovery that is required for optimal performance. If this mismatch is not corrected, athletes may be susceptible to decreased performance, fatigue, illness, and/or injury, otherwise known as overreaching and/or overtraining.

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CHAPTER 3

TOLERABILITY OF HEAVY TRAINING LOAD AND MONOTONOUS TRAINING

Introduction

Training is considered monotonous (M) when there is little variation in the day to day training load (TL). A monotonous training pattern is of concern to athletes and coaches because M training may interrupt the cycle of training and recovery, leading to negative rather than the desired positive training adaptations and improved performance. Bruin et al. (1994) showed that when horses followed a hard day-easy day training program, they were able to complete the prescribed TL. On the other hand, when the program was made more M by increasing the intensity on the easy days, the horses were unable to complete the prescribed TL.

A few studies with human athletes have shown that a high TL in combination with a highly M training pattern can lead to illness and/or injury (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003; Bruin, Kuipers, Keizer, & Vander Vusse, 1994; Foster, 1998). These illnesses and/or injuries can be of varying type, severity, and required recovery time, but one commonality is that all of the symptoms are associated with a decrease in performance despite an increase in TL (Kuipers & Keizer, 1988). Since the clustering of symptoms is consistent with the concept of a syndrome, the term overtraining syndrome (OTS) has been adopted to describe the set of negative responses that may be associated with the combination of a high TL and highly M training. Because of the variability in the type and severity of symptoms, as well as recovery time, it is hypothesized that OTS is best represented by a continuum with overreaching at one end of the continuum and overtraining at the other end. More specifically, overreaching is associated with short-term performance decrements and overtraining is associated with long-term performance decrements. The idea that overreaching will lead to overtraining if adequate recovery time is not allowed is also consistent with the concept of an OTS continuum (Halson & Jeukendrup, 2004). In other words, if an athlete does not allow for adequate recovery after training, a state of decreased performance will occur and the longer the time period without adequate recovery the longer the duration of the decreased performance, which may last weeks, months, or years, possibly robbing an athlete of his/her career (Budgett, Newsholme, Lehmann, Sharp, Jones, Peto, Collins, Nerurkar, & White, 2000).

Given the potential consequences of overtraining, prevention is an important objective. Unfortunately there is no single sign or symptom that indicates the onset of OTS. Rather there are many signs and symptoms that may be associated with OTS, including fatigue, disrupted mood state, lingering aches and pains, altered lactate response, disrupted sleep patterns, and loss of appetite to name a few (Budgett, 1998; Foster, 1998; Fry, Morton, & Keast, 1991; Gutmann, Pollock, Foster, & Schmidt, 1984; Halson & Jeukendrup, 2004; Hooper, Mackinnon, Howard, Gordon, & Bachmann, 1995; Kentta & Hassmen, 1998; Lehmann, Foster, & Keul, 1993; Snyder, Jeukendrup, Hesselink, Kuipers, & Foster, 1993; Urhausen & Kindermann, 2002).

The variability of symptomology has made early identification of overreaching difficult, but subjective complaints (mental state, fatigue, body aches, etc.) are typically recognized as one of the first indicators that an athlete has not had adequate recovery and is making negative, rather than positive adaptations to training. These complaints can be quantified as a complaint index (CI) and monitored on a daily basis; thus monitoring the CI of athletes may be a useful tool in the prevention of OTS (Foster, 1998). With regular monitoring, coaches and/or support staff may recognize signs and symptoms of early OTS (or overreaching) before performance decreases to a great extent. By monitoring the TL and M of individual athletes, coaches can have an idea of the internal load being imposed on each athlete.

Training load can be monitored using the modified TRIMP (mTRIMP) method of calculating TL from training session duration and session rating of perceived exertion (SRPE) (Foster, Hector, Welsh, Schrager, Green, & Snyder, 1995; Foster, 1998). An index of M shows the day to day variation in TL and is calculated by dividing the average daily TL for a week by the standard deviation of the weekly TL. Strain (S) represents the effect of both TL and M on the athlete, and is calculated as the product of TL and M. The internal load is thought to be reflected in the subjective CI feedback provided by athletes. Early identification of an excessive internal load might make it possible to alter TL so that OTS is avoided; however, more support for the use of CI and TL and M information as an indicator of the internal load is needed.

The purpose of this study was to determine if a threshold for TL, M, and/or S could be identified for a nonlinear increase in the subjective complaints of athletes, indicating that the internal load is too high because the athletes have not had adequate recovery. We hypothesized that TL, M, and S will be significantly related to subjective complaints and that individual athletes will exhibit thresholds for TL, M, and S at the point where subjective complaints increase non-linearly.

Methods

Participant selection. Archive data that included training information from 5 male and 4 female elite long track speed skaters (including 5 Olympians) that was collected for the U.S. National Team coaches was used to test the hypothesis. Athletes with complete TL records for the Preparation Phase (PP) of the season were used for analysis. The speed skaters ranged in age from 21-30 at the time of data collection. Each athlete met the specific selection criteria required to be selected to the U.S. National Speed Skating Team, including time standards and results from previous seasons.

Procedures. Elite long track speed skaters training with the U.S. National Team began training with the team in May. This period of the season is known as the Preparation Phase (PP), and included training sessions that were long in duration and/or difficult in intensity. During the PP the coach provided the athletes with a specific training program that included the type of training (i.e., cycling, skating, weight training), duration of training (min), and intensity of training (RPE). The coaches followed a typical periodization plan of training with relatively easier training days following relatively harder training days and a two hard week-one easy week overall pattern. During the PP, training typically occurred once or twice a day, 6 days of the week. The U.S. National Team athletes were required to report their training information on a session by session basis to the coach or sport scientist. Athletes reported the duration of the training session (in minutes) and the session intensity based on the Category Ratio

Rating of Perceived Exertion (SRPE) scale (Foster et al., 1997). The TL executed by the athletes was calculated as the product of the session duration (min) and the SRPE, resulting in a dimensionless number that was used for analysis. M was calculated by dividing the average daily TL by the standard deviation of the weekly TL (Foster & Lehmann, 1994). S was calculated as the product of TL and M. TL, M, and S were calculated on a weekly basis. Non training information that was reported included Mental Well-Being (MWB, Table 3.1) and Muscle Aches and Pains (MAPE, Table 3.1), and was also collected on a daily basis. The daily complaint index (CI) was calculated by multiplying MWB and MAPE.

Statistical methods. Pearson product moment correlations were used to determine if a relationship exists between daily CI's and 7-day TL, M, and S. Significance for Pearson product moment correlations was set at ≤ 0.05. Curvilinear graphing procedures were used to determine if a threshold exists (breakpoint in the curve) (Foster & Lehmann, 1997).

Table 3.1 Subjective Rating for Mental Well-being and Muscle Aches and Pains

	Mental well-being	Muscle aches and pains
1	Feel great	None, muscles feel great
2	Feel ok, let's get on with business	A little achy, about normal
3	I'm here, don't expect a celebration	Pretty achy, better after warm-up
4	Let's get this over with	Still pretty achy after warm-up
5	Why am I wasting my life with this stuff	Do I have to get out of bed

Results

Despite the substantial average weekly TL (5197 ± 623) achieved by these athletes *(for comparison 2hr daily @RPE = 5 (hard) would be 4200)*, M was very low (1.07 ± 0.05), and few cases of increased CI (≥ 9) were observed over 112 training sessions for the nine athletes. Overall the Pearson product-moment correlations were very weak to moderate ($r = 0.003$ to $r = 0.40$) for 7-day TL and CI, very weak to weak ($r = 0.02$ to $r = 0.25$) for M and CI, and very weak to moderate ($r = 0.0003$ to $r = 0.34$) for S and CI (Table 3.2). Individual graphs showed no apparent breakpoint in the curve to determine a threshold for TL, M, or S due to the low incidence of increased CI.

Discussion

While highly M training at high TL has been shown to contribute to negative training adaptations to training, the well periodized training plan (e.g., low M) designed by the coaches of these athletes allowed them to tolerate very high TL with few negative outcomes. The strain (S) of training (TL*M) appeared to have some relationship with CI. This may suggest that the overall S of training may lead to negative adaptations

Table 3.2 Pearson Product-moment Correlations for TL, M, and S with CI

Athlete	TL versus CI	M versus CI	S versus CI
1	0.25*	0.25*	0.32*
2	0.12	0.25*	0.18
3	0.07	0.12	0.09
4	0.40*	0.11	0.31*
5	0.24*	0.10	0.19*
6	-0.06	0.19*	0.01
7	0.05	-0.03	0.01
8	0.40*	0.09	0.34*
9	0.003	0.02	0.0003

*Significant correlation ($p \leq 0.05$)

regardless of the TL or M. As expected TL, and therefore S, increased during this training period. It appears that as the athletes adapted to the training, they were able to tolerate higher and higher TL and S during the training phase, as shown by an increase in TL and S with no subsequent prolonged increase in CI.

One limitation of the study is that the recovery techniques employed by these athletes were not taken into account. Recovery techniques including massage, ice bath, compression garments, or others may enhance recovery between training sessions and allow athletes to tolerate the increasing load required to improve performance (Barnett, 2006). Another limitation of the study is that the coaches were free to adjust the training plan as needed based on the feedback of the athletes and the coach's sense of how the athletes were doing. This may have affected the TL, M, and S eventually executed by the athletes, which may have kept the incidence of increased CI low.

Although a strong relationship was not established in detecting negative adaptations to training with TL, M, or S, daily/weekly monitoring of athletes using CI, TL, M, and S may help to detect negative adaptations before they become irreversible. These tools for monitoring may be especially important early in the season when athletes must be able to tolerate progressively increasing loads to achieve the positive adaptations required for improved performance.

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CHAPTER 4

VARIATIONS IN SWIM TRAINING PATTERN ON POSITIVE AND NEGATIVE OUTCOMES OF TRAINING

Introduction

Athletes strive to improve performance by progressively increasing training loads (TL), while allowing adequate time for recovery (Budgett, 1998; Budgett et al., 2000; Fry, Morton, & Keast, 1991, 1992; Kentta & Hassmen, 1998). The balance between training and recovery can typically be maintained by varying the training duration and/or intensity (Smith, 2003). Training is considered monotonous (M) when there is little variation in the day to day TL (Foster & Lehmann, 1997). A monotonous training pattern is of concern to athletes and coaches because M training may interrupt the cycle of training and recovery, leading to negative rather than the desired positive training adaptations and improved performance. Bruin et al. (1994) showed that when horses followed a hard day-easy day training program, they were able to complete the prescribed TL. On the other hand, when the program was made more M by increasing the intensity on the easy days, the horses were unable to complete the prescribed TL, and exhibited symptoms similar to those in humans suffering from overtraining syndrome (OTS).

Although some studies have associated a high TL in combination with a highly M training pattern with increased illness and/or injury (Anderson, Triplett-McBride, Foster, Doberstein, & Brice, 2003; Bruin, Kuipers, Keizer, & Vander Vusse, 1994; Foster, 1998), there are no studies that we are aware of that have prescribed a M training pattern to determine the effect on subjective complaints and performance. A decrease in performance is the gold-standard marker for diagnosing an athlete as overreached or overtrained. An increase in subjective complaints typically occurs prior to or along with a decrease in performance, and may be important in the detection and prevention of overreaching and OTS.

Training load can be monitored using the modified TRIMP (mTRIMP) method of calculating TL from training session duration and session rating of perceived exertion (SRPE) (Foster, 1998). An index of M shows the day to day variation in TL and is calculated by dividing the average daily TL for a week by the standard deviation of the weekly TL. Strain (S) represents the effect of both TL and M on the athlete, and is calculated as the product of TL and M. The internal load is thought to be reflected in the subjective CI feedback provided by athletes (Foster & Lehmann, 1997). Early identification of an excessive internal load might make it possible to alter TL so that OTS is avoided.

The purpose of this study was to increase the M in a training plan for a group of athletes and compare the weekly performance and subjective complaint values with athletes completing a low M or polarized (hard-easy) training plan.

Methods

*Participant selection***.** Archive data from the University of Wisconsin-La Crosse swim team was used for the study. The team consisted of 62 athletes (34 female, 28 male). Participants were included in the study on the basis of the following inclusion criteria: adherence to assigned training program, limited number of absences, and consistent recording of training data. At the end of the 11-week period, 40 participants (23 female, 17 male) met the inclusion criteria and were included in the study.

*Procedures***.** Athletes were randomly assigned to either a Polarized training group (PG), or a Monotonous training group (MG). The PG was prescribed a swim training pattern by the coach, with training days alternating between hard and easy. The MG was prescribed an altered swim training pattern by the coach, with all training days consisting of medium to hard training. Both groups were prescribed a similar total weekly TL.

Following each training session each athlete recorded the following training and non training data: training duration (minutes), training intensity (SRPE), mental well-being (MWB), and muscle aches and pains (MAPE). TL was calculated as the product of training session duration and SRPE. M was calculated on a weekly basis as the average daily TL divided by the standard deviation of the TL. S was calculated as the product of TL and M. The complaint index (CI) was calculated as the product of MWB and MAPE. All athletes performed a 200 meter time trial (TT) on a weekly basis following a normal warm-up, which served as the performance measure.

Statistical methods. A two-way mixed repeated measures ANOVA (group x weeks) was used to determine whether or not there was a significant difference between the PG and MG groups for TL, M, S, CI, and weekly TT. The Statistical Package for the

Social Sciences software (SPSS Inc., Chicago, IL, version 19.0) was used to perform statistical analyses. Significance level was set using a Bonferroni correction at ≤ 0.01.

Results

Training load. There was no statistically significant difference between PG (n = 21) and MG (n = 19) for weekly TL (F = 0.39, p = 0.54, Figure 4.1). TL for both groups was significantly different over the 11-week training period.

Monotony index. There was no statistically significant difference between PG and MG for M (F = 0.24, p = 0.63, Figure 4.2), although during most weeks M was higher for MG. During week 6, M was significantly higher for MG than for PG (1.05 ± 0.16 versus 0.89 ± 0.15, p = 0.003).

Strain. There was no statistically significant difference between PG and MG for S (F = 0.51, p = 0.48, Figure 4.3).

Complaint index. There was no statistically significant difference between PG and MG for the average weekly CI (F = 0.15, p = 0.7, Figure 4.4). During week 6, MG showed a higher CI than PG (4.73 ± 5.06 versus 2.74 ± 1.85), but this was not significant.

Time trial performance. There was no statistically significant difference between PG and MG for weekly TT (F = 1.06, p = 0.31, Figure 4.5). Both groups showed a significant improvement over the 11-week training period (p = 0.00).

Discussion

The purpose of the current study was to deliberately increase M for one group of athletes during an 11-week training period to compare the weekly performance and subjective complaint values with athletes completing a low M or polarized (hard-easy) training plan with a similar overall weekly TL. Both groups executed a similar weekly

TL (PG=2484 ± 137, MG=2610 ± 1387) over the 11-week time period as planned. Although not significant, M values for MG were higher than PG for 7 out of 11 weeks, albeit not to the magnitude planned. To offset the lack of variability in the training program with all sessions prescribed at medium to hard intensity, the MG self-prescribed additional rest days. These rest days decreased the monotony of training, and allowed the athletes to recover. This was evident by the lack of an increase in CI and a significant improvement in 200-m TT performance.

The monotonous group showed an increase in TL and M from week 4 to week 6, which also increased S. These factors combined resulted in an increase in CI and a subsequent decrease in performance during week 7. This provides some evidence that an increase in the subjective complaints of an athlete on the verge of overreaching may precede a decrease in performance.

Overtraining syndrome is a common problem that can be very detrimental to the career of an athlete. The close monitoring of athletes may be a strategy to detect and prevent overreaching and/or OTS. Many athletes are well in tune with their bodies, and understand the fine balance between training and recovery. Their feedback can be a tool to adjust training programs to optimize the positive adaptations to training and minimize the negative adaptations and prevent a decrease in performance.

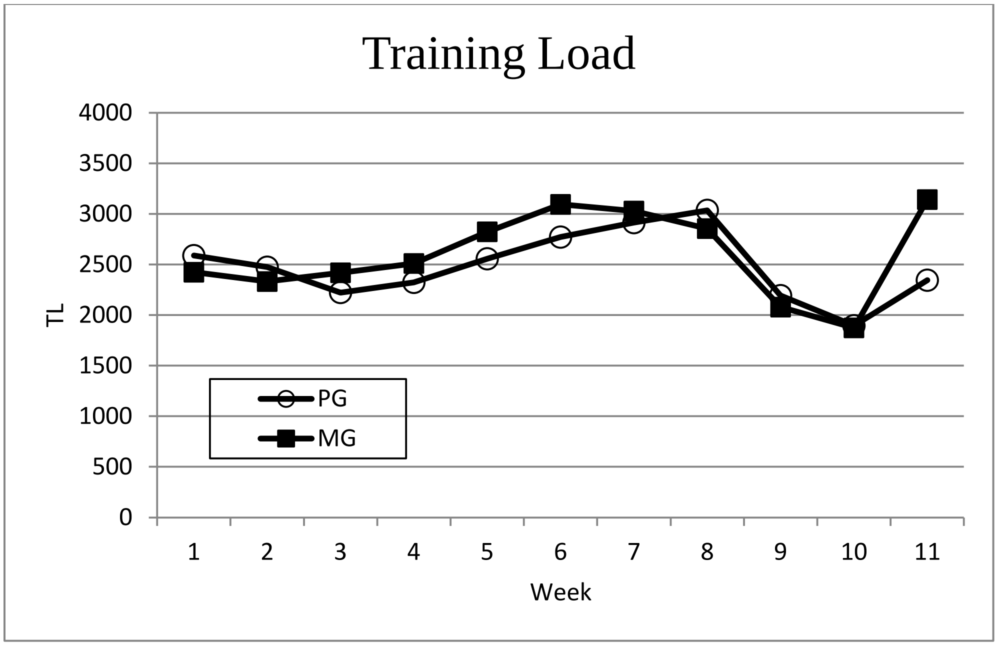

Figure 4.1. Weekly TL for polarized group (GP) and monotonous group (MG)

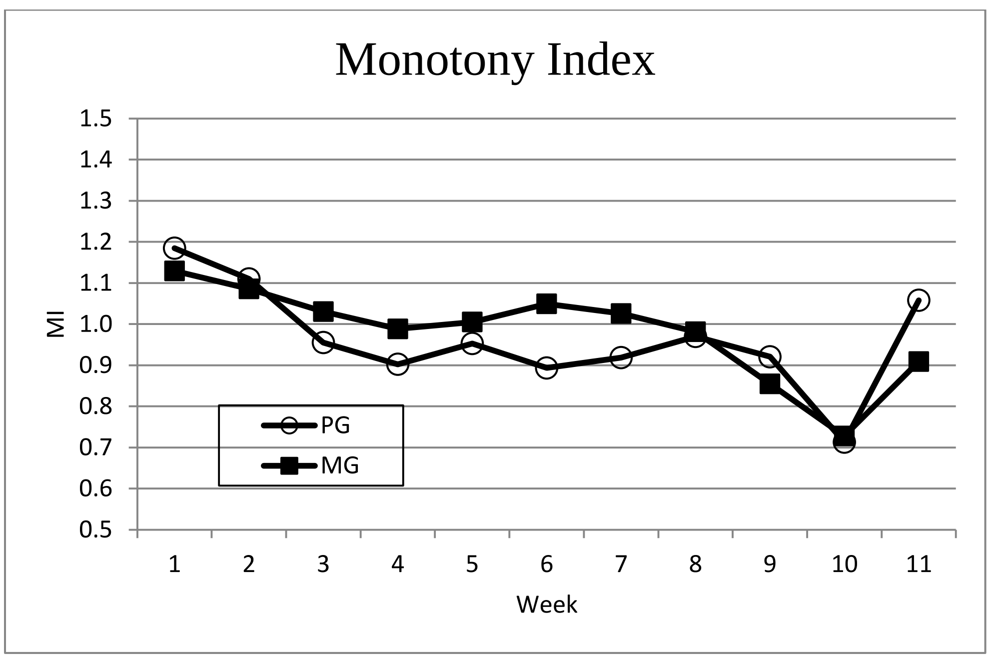

Figure 4.2. MI for polarized group (GP) and monotonous group (MG)

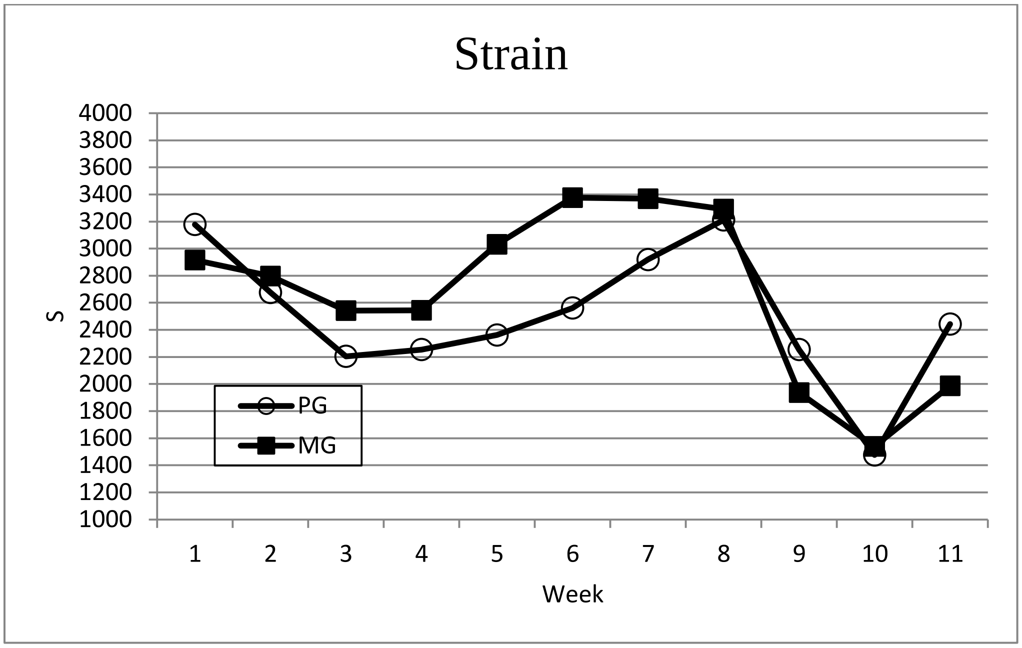

Figure 4.3 S for polarized group (PG) and monotonous group (MG)

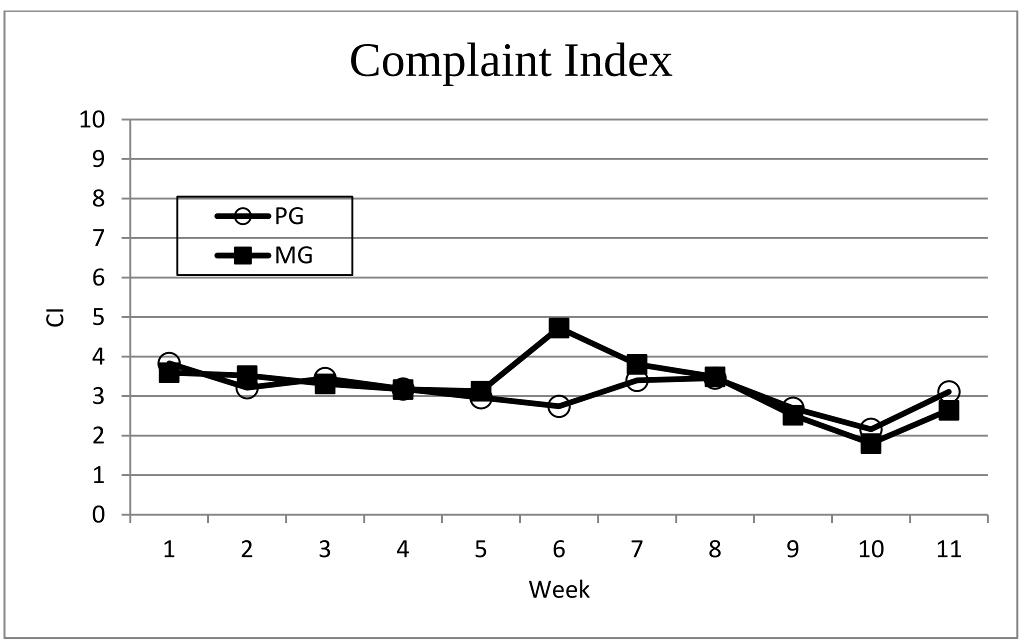

Figure 4.4. CI for Polarized Group (PG) and Monotonous Group (MG)

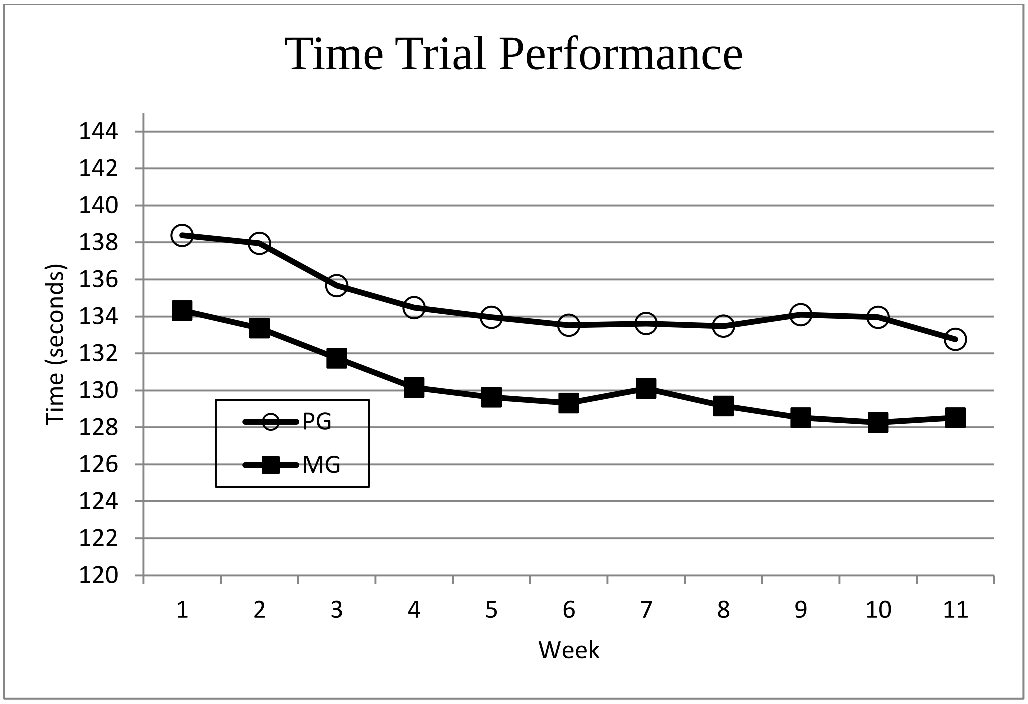

Figure 4.5. Weekly TT time in seconds for Polarized Group (PG) and Monotonous Group (MG)

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CHAPTER 5

DISCUSSION

The goal of athletic training is to maximize the positive adaptations associated with training while minimizing the negative adaptations associated with training to improve performance potential. This path is very complex and highly individual. A fine balance exists between the correct amount and intensity of training and the necessary recovery time. When this balance is disrupted, a decrease in performance may occur, along with other physical, physiological, and psychological signs and symptoms. It is critical to utilize a strategy of monitoring that provides an accurate training and recovery status of an athlete.

The purpose of these three studies was to assess the practicality and value of using the modified TRIMP (mTRIMP) method of quantifying training in different training circumstances and with different athlete populations. The mTRIMP has been shown to be a valid tool to monitor the physical and psychological load imposed on athletes during training. This method is less burdensome than previous methods and can be used to track training for a session, day, week, or longer.

Coaches plan training with the assumption that athletes follow the prescribed training. Previous research has shown that athletes do not always execute the training load (TL) the coach has planned. We aimed to determine if the presence or absence of a coach would have an effect on the agreement between the actual TL of athletes and the planned TL of coaches. Although there was good agreement between actual TL and planned TL in a group of elite speed skaters, when the coach was absent and the TL was designed to be lower, many athletes had a tendency to execute a higher TL than was planned. This in turn may have caused the athletes to execute a lower TL than was planned when the coach was present for the planned higher TL sessions. This may decrease the daily variability in training, leading to a more monotonous (M) training pattern. It has been shown that highly M training may lead to signs and symptoms associated with overreaching and OTS and a decrease in performance.

Previous research has shown that individual thresholds for TL, M, and strain (the combination of TL and M, (S)), can account for a high percentage of illnesses and injuries in athletes. It is often thought that subjective complaints are a precursor to illness and/or injury, decreased performance, and overreaching and/or overtraining. We aimed to determine if individual thresholds could be detected for TL, M, and S that caused a significant increase in the subjective complaints in a group of elite speed skaters. Although a strong relationship was not established in detecting negative adaptations to training with TL, M, or S, daily/weekly monitoring of athletes using a complaint index (CI) comprised of mental well-being (MWB) and muscle aches and pains (MAPE), TL, M, and S may help to detect negative adaptations before they become irreversible. These tools for monitoring may be especially important early in the season when athletes must be able to tolerate progressively increasing loads to achieve the positive adaptations required for improved performance later in the season.

Although highly M training is thought to be deleterious to performance, there have been no studies that have compared a polarized (hard day-easy day) training group to a monotonous training group in regards to performance and subjective complaints. We aimed to deliberately increase the M in the training plan for a group of athletes and compare the weekly performance and subjective complaint values with athletes completing a low M or polarized training plan with a similar weekly TL. Training load was not significantly different for the two groups over the 11-week training period as planned. However, the two groups did not show a significant difference in M over the 11-week training period, although the monotonous group was higher for 7 out of the 11 weeks. Athletes in the M group took more self-selected rest days, which decreased the overall M of the training program. When M did increase there was a tendency for subjective complaints to increase, and performance to decrease, although these changes were transient and reversed with a decrease in M. It appears that in this level of athlete, the required imbalance between training and recovery that results in signs and symptoms of overreaching is difficult to elicit due to the athletes' willingness to take days off to enhance recovery.

Monitoring athletes' training and responses to training are a critical component of the training process required to achieve optimal performance. The mTRIMP method is a practical tool that provides valuable feedback to the coach to assist them in making adjustments to the training program in an attempt to detect and prevent overreaching and/or overtraining. Although our studies did not detect or provoke any of the early signs of overreaching or OTS, this is a problem that can affect many athletes during their career. Through the monitoring process, coaches can have a better understanding of whether or not athletes are executing the prescribed training, if the training is causing negative adaptations, and if additional recovery time is needed to avoid overreaching and/or overtraining.